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## **Response of Gopher Tortoises to Habitat Manipulation by Prescribed Burning**

Can Forested Areas Adjacent to Training Areas Be Improved?

Lisa Yager, Matt Hinderliter, and Harold Balbach

April 2006

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## ABSTRACT

The gopher tortoise (*Gopherus polyphemus*) is a terrestrial reptile that was once quite plentiful throughout the Southeastern United States from South Carolina into Louisiana. However, because of factors such as habitat loss to agriculture and urbanization, and human and animal predation, their numbers have been in decline for the past several decades. In addition to population decline throughout its range, the tortoise has maintained only a limited, precarious existence in extreme southern South Carolina and extreme eastern Louisiana. Camp Shelby, Mississippi, supports one of the largest tortoise populations within the federally listed, western range of the tortoise. However, within the military use areas, the animal shows a habitat preference for the artificially maintained training openings in the forest, placing it at greater risk for accidental injury. This report describes attempts that have been made to determine what type and degree of habitat changes will be necessary to make more suitable tortoise habitat available.

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## PREFACE

The research documented in this report was performed during the period 2000 through 2004 as part of Work Unit CNN-T011, Maneuver Disturbance Assessment for the Conservation Program, “Training Lands Management—Characterization, Analysis, and Mitigation,” under program element P622720, Army Environmental Quality Technology. This research was conducted under the guidance of Dr. Harold Balbach, Principal Investigator, U.S. Army Engineer Research and Development Center, Construction Engineering Research Laboratory (ERDC/CERL), in support of the Army Threatened and Endangered Species Research Program. The research was conducted and compiled by Dr. Deborah Epperson, Colleen Heise, Lisa Yager, and Matt Hinderliter, all associated with the Camp Shelby Field Office, and all at the time of their involvement employed by the Mississippi Chapter of The Nature Conservancy.

In addition to support under the Army Threatened and Endangered Species research program, financial support and field and administrative assistance was also provided by the Mississippi Army National Guard and by the U.S. Forest Service, DeSoto National Forest.

At the time of this report’s publication, Steve Hodapp was the TES Program Manager, Alan Anderson was Chief, CEERD-CN-N, and Dr. John T. Bandy was Chief, CEERD-CN. The associated Technical Director was Dr. William D. Severinghaus, CEERD-CV-T. The Acting Director of CERL was Dr. Ilker Adiguzel. The Commander and Executive Director of ERDC was Colonel James R. Rowan, and the Director of ERDC was Dr. James R. Houston.

# **Response of Gopher Tortoises to Habitat Manipulation by Prescribed Burning Can Forested Areas Adjacent to Training Areas Be Improved?**

LISA YAGER, MATT HINDERLITER, AND HAROLD BALBACH

## **1 INTRODUCTION**

### **Background**

The gopher tortoise (*Gopherus polyphemus*) is a terrestrial reptile that was once quite plentiful throughout the Southeastern United States from South Carolina into Louisiana. However, because of factors such as habitat loss to agriculture and urbanization, and human and animal predation, their numbers have been in decline for the past several decades. In addition to population decline throughout its range, the tortoise has maintained only a limited, precarious existence in extreme southern South Carolina and extreme eastern Louisiana. Camp Shelby, Mississippi, supports one of the largest tortoise populations within the federally listed, western range of the tortoise. However, within the military use areas, the animal shows a habitat preference for the artificially maintained training openings in the forest, placing it at greater risk for accidental injury. This project attempts to determine what type and degree of habitat changes will be necessary to make more suitable tortoise habitat available to the animals.

### **Species Description**

The adult gopher tortoise is a medium-sized land turtle, the only native tortoise in its range. While moderate geographical variations have been noted (Landers et al. 1982), the average size is accepted to be within the range of 9–11 inches (23–28 cm) in length, weighing 8–10 pounds, with extremes reported at 14 inches (36 cm) and 15 pounds (6.8 kg) (Dietlein and Franz 1979). They lack the webbed feet of an aquatic turtle, and have distinct submaxillary gular glands and an unhinged shell (Auffenburg 1978; Ernst and Barbour 1972). The tor-

toise's shell is domed and will vary by population in color from light tan to a darker gray. Description in the literature is rather abundant with little to no controversy. *G. polyphemus* is the only tortoise both within its range and east of the Mississippi River. Three other tortoises in the genus *Gopherus* are found in North America: the Texas tortoise (*G. berlanderi*), the desert tortoise (*G. agassizii*) of the California, Arizona, and Nevada deserts, and the Bolson tortoise (*G. flavomarginatus*) of northern Mexico. All species are considered to be at risk at this time.

### *Distribution*

As stated earlier, the species distribution has declined substantially from its original range. Now found, often sporadically, only from extreme southern South Carolina to far eastern Louisiana, its decline is quite similar and related to that of the red-cockaded woodpecker. Like the woodpecker, the tortoise was most often found in upland, open canopy woodlands of the longleaf pine ecosystem. These lands were characterized by open pine forest and plentiful ground cover vegetation that constitutes the tortoise's diet. Although a comprehensive list of military facilities with gopher tortoise populations probably has not been completed, Wilson et al. (1997) listed 18 military installations with documented on-site *G. polyphemus* populations. In addition to Camp Shelby, Mississippi, major populations of *G. polyphemus* exist on Camp Blanding, Florida; Forts Benning and Stewart, Georgia; and Eglin Air Force Base, Florida.

### *Habitat*

A strong influence in this ecosystem is frequent wildfire, which controls midstory growth. The longleaf pine is markedly fire-resistant, and ground cover recovers rapidly and is even enhanced by fire. A positive, linear relationship usually exists between herbaceous ground cover and tortoise population densities (Auffenburg and Iverson 1979), with areas of generous ground cover (80 percent) supporting up to 20 times more tortoises than areas of sparse ground cover. The open canopy is essential not only for ground cover growth and providing nutrition, but also to provide ground temperatures conducive to hatching the tortoise eggs (Landers et al. 1982). The interactivity of ecosystem factors must be noted. Longleaf pines provide an open canopy, the fire suppresses the midstory that would otherwise suppress the ground cover, and the ground cover feeds the tortoise. Several predictors have been attempted to characterize gopher tortoise habitat. Cox et al. (1987) provided a copious, comprehensive account of 32 vegetation communities supporting *G. polyphemus* in Georgia and Florida. Soil types were described by Auffenburg and Franz (1982), Lohoefer (1982), and



Landers et al. (1982). These reports most importantly described sandy soils that allow rapid drainage and easy digging, though they also alluded to some tortoise populations in clay soils, and others in shallow soils underlain by hardpan. Ruderal areas have also become increasingly important (Auffenburg and Franz 1982, Epperson and Heise 2001).

### *Legal Status*

The western population of *G. polyphemus* is federally listed as Threatened. This population occurs in extreme southwestern Alabama (three counties), extreme eastern Louisiana (three parishes), and all of southern Mississippi. The tortoises at Camp Shelby, Mississippi, are thus within this federally listed range. The other states with the tortoise share a Federal status of *species of concern* or, in the current usage, a *species at risk*. State status of the tortoise varies. Mississippi and South Carolina both list the tortoise as Endangered; Louisiana and Georgia list it as Threatened. Florida has it as a *species of special concern*, while in Alabama it is a protected nongame species. To some degree, these listings parallel the state of local populations, with those having the smallest remaining numbers given the highest status. Significantly, the species is decidedly in decline throughout its range and, if this trend is not reversed, more stringent listings can be expected.

From experience following the listing of the red-cockaded woodpecker, it appears clear that Federal listing of the eastern tortoise populations has the potential to significantly impair Army mission uses at affected locations. Numerous Army-sponsored research projects, including the one reported here, seek to increase knowledge of tortoise needs and to improve management practices to ensure survival and sustainment of the species so as to preclude the need for more widespread Federal listing within its eastern populations.

### **Problem**

The gopher tortoise, as noted above, shows a strong preference for placement of its burrows in open, sunny areas. Originally, this was ideally the forest floor associated with the relatively open canopy of longleaf and other pine forests where natural fire was common, and where this frequent fire reduced or eliminated the understory shrubs and tree seedlings. In areas where regular fire has been suppressed, as has been common for the last 50 to 75 years in much of its range, this understory has become well developed and dense, resulting in a shaded forest floor. The tortoises find these habitats less than ideal, and also are unable to find adequate forage of herbaceous plants there. Both conditions lead to disuse or abandonment of habitat that was previously satisfactory and occupied.



**Figure 1. M109 artillery battery firing from a Camp Shelby firing point clearing.**

At Camp Shelby, Mississippi, the fire suppression, or at least relatively infrequent use of prescribed burning, has resulted in forest understory conditions where the tortoises do not survive, or at least do so only in much reduced numbers. At the same time, numerous artificial openings have been created for training use by artillery batteries (Fig. 1). These openings, up to several hectares in size, provide places for the artillery units to emplace the guns and fire into an impact area that may be several thousand meters distant. When in use, a dozen or more wheeled and tracked vehicles may move into these areas, establish their position, and then fire from one to several howitzer shells at a time. After this, they normally move to another site to repeat the act, which replicates one of the required training skills for an artillery unit.

Many of these artificial openings, however, are also heavily used by tortoises, which create burrows in the bright, sunny areas. By doing so, however, there is a much greater likelihood that the Army vehicles will accidentally crush a tortoise while maneuvering in and out of their firing positions. Were the animals to remain within the forest, or even at the forest edge, there would be a greatly reduced chance that they would be injured or killed. The problem is, thus, to determine whether relatively simple habitat manipulation actions will induce tortoises to occupy, or at least make greater use of, forest habitat where they will

have a greater degree of safety, and reduce reliance on the riskier habitat within the artillery firing point.

### **Approach**

The approach utilized in this multi-year study was to identify eight firing points with resident tortoises, each with a 200-m buffer of surrounding forested habitat. All sites were of similar habitat quality and had similar soils. The eight sites were divided into four experimental sites, where controlled burns of the site and adjacent forest were conducted, and four control sites, which were not manipulated. Control sites were not burned during the study; treatment sites were burned during the winter of 2001/2002 and in April 2003. Vegetation was sampled along transects at each site in each year to document changes in vegetation over time in both the treatment and control sites. Annual burrow surveys were conducted and selected adult tortoises were monitored by both radio-telemetry and powder tracking. Changes, if any, in tortoise burrow distribution and density, patterns of tortoise usage of the habitat, and in several vegetation parameters were measured initially and at several stages during and after the final treatments.

### **Mode of Technology Transfer**

The information included in this report is one portion of the materials prepared by the Engineer Research and Development Center (ERDC) to assist installation natural resources and TES program managers. The primary means of communicating the tortoise behavior information will be through publication in the scientific literature, as well as through the availability of this report. The specific data presented are intended to be used in the preparation of biological opinions related to planned Army actions where the gopher tortoise is present. The data also will be used for endangered species management plans (ESMPs), integrated natural resources management plans (INRMPs), and in the preparation of ecological risk assessments involving training and other land-disturbing activities where the tortoise is present. This report will be made accessible through the World Wide Web (WWW) at URL <http://www.cecer.army.mil>.

## 2 METHODS

### Background

The year 2005 was the fourth and final year of a study researching the effects of habitat management by prescribed fire on gopher tortoises (*Gopherus polyphemus*) on Camp Shelby Training Site (CSTS), an approximately 134,000-acre Army National Guard Training Site located in southern Mississippi. The majority of the land (85%) is within DeSoto National Forest and is used by the Army National Guard under a special use permit from the United States Forest Service (USFS).

Gopher tortoises located west of the Mobile and Tombigbee rivers in Alabama are federally listed as threatened. They have been documented on 18 military installations (Wilson et al. 1997); however, Camp Shelby is currently the only military installation with federally protected gopher tortoises. Current estimates range from approximately 1,000 to 2,000 adult tortoises on Camp Shelby.

Gopher tortoises have three major habitat requirements: 1) sandy soils in which to dig burrows and lay their eggs, 2) an open-enough canopy so that light reaches the ground for incubating eggs, and 3) a plentiful and diverse herbaceous ground cover for foraging. In areas that are managed for gopher tortoises, canopy cover should be less than 80% and it is often recommended that canopy cover be less than 60% (Landers et al. 1981, Cox et al. 1987). Tortoises on Camp Shelby are found in longleaf pine forests that are regularly burned; however, a large percentage of tortoises on Camp Shelby are found in ruderal areas (Epperson and Heise 2001). These are areas that have been cleared of trees and are maintained with a predominantly herbaceous ground cover by annual dormant season mowing mixed with occasional burning. They are typically maintained in a ruderal state for military training and are often used as firing points and ranges.

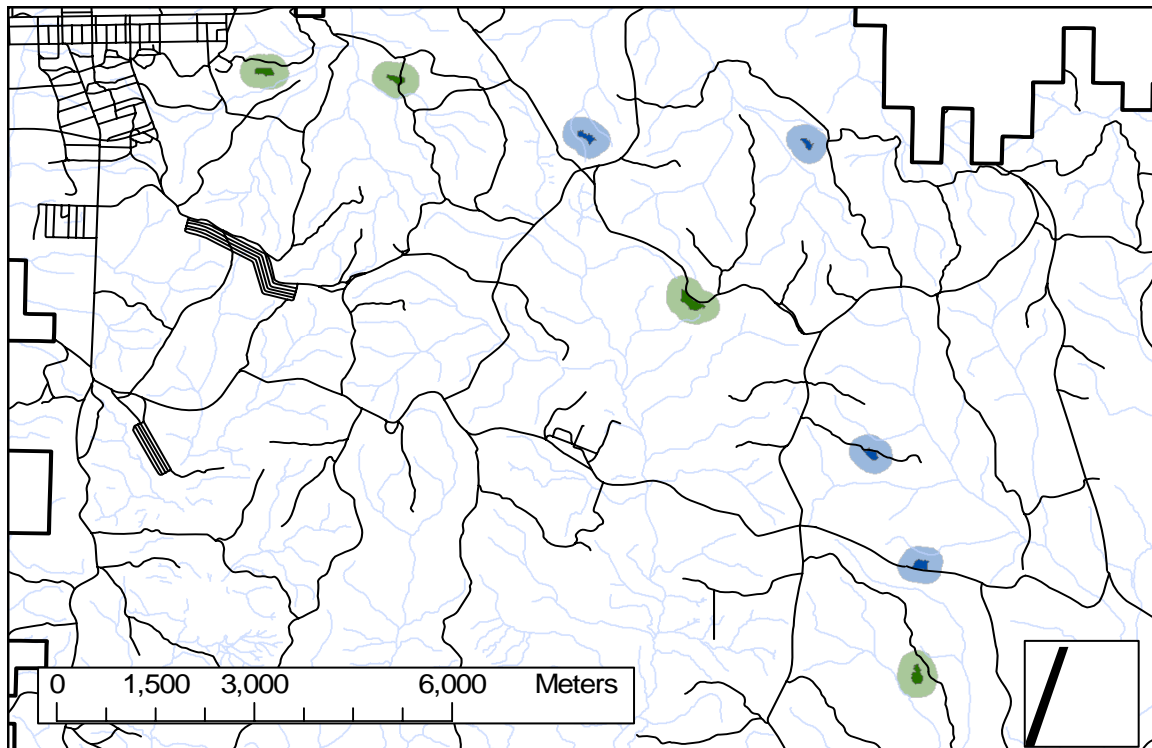
Prescribed fire is used as a forestry management technique on Camp Shelby; however, due to drought years and lack of funding, much of the pine forest habitat has not been burned as regularly as is necessary to maintain good gopher tortoise habitat. This has led to an increase in shrubby, midstory vegetation and a decrease in herbaceous ground cover in many of the upland pine forests historically used by gopher tortoises. Most of the ruderal habitat is surrounded by overgrown forested habitat and tortoises are increasingly using the ruderal areas. This is potentially dangerous for the tortoises, as well as being problematic for the

military, which must adhere to guidelines in and around gopher tortoise colonies and burrows.

This research was initiated to determine whether the forested lands around ruderal areas could be sufficiently improved using prescribed fire so that tortoises would increase forested land use and decrease their dependency on the ruderal areas. Objectives of this research were to 1) determine whether reintroduction of fire in fire-excluded forested habitat surrounding ruderal areas inhabited by gopher tortoises will restore habitat conditions suitable for gopher tortoises and 2) to determine response of tortoises to the habitat restoration. Changes in vegetation in adjacent forest and firing point treatment (burn) and control sites were measured to determine effectiveness of prescribed fire in enhancing habitat for gopher tortoises. Response of tortoises to habitat change was tested by monitoring movements, home range, and burrow use of tortoises in treatment (burned) and control sites to determine whether tortoises in the treatment sites increase their use of the forested areas.

### Study Design

Eight firing points, each with a gopher tortoise colony, were chosen as study sites (Fig. 2). Each firing point and the 200-m buffer of forested habitat surrounding it were considered a study site; all sites were of similar habitat quality and had similar soils. The majority of upland soils within the sites are sandy loams (NRCS soil surveys for Forrest and Perry counties). Firing points are upland sites maintained with a predominantly herbaceous ground cover by mowing and/or burning. Non-native species such as *Paspalum notatum*, *Cynodon dactylon*, and *Lolium perenne* have been planted for erosion control and are mixed with native species. Adjacent forested habitat varied within the buffers depending upon topography, past management, and edaphic and other features, but could generally be described as mature pine forest with a well-developed shrub midstory and minimal herbaceous ground cover. The four sites assigned as control sites were not burned during the study, and the four sites assigned as treatment sites were burned during the winter of 2001/2002 and in April 2003. Sites were burned by the USFS as part of a larger USFS compartment. In many areas the midstory vegetation had become so overgrown that initially conducting a growing season burn would have been potentially dangerous and likely would have killed many of the timber trees. It was therefore decided to conduct dormant season burns during 2001/2002 to reduce midstory vegetation, followed by growing season burns in late April 2003.



**Figure 2. Locations of control (green) and burned (blue) sites for the habitat study on the Camp Shelby Training Site. Roads (in black) and streams (in blue) are also shown.**

Vegetation data were collected along transects oriented from firing points into adjacent forest and around burrows. Vegetation was sampled along transects each year to document changes in vegetation over time in both the treatment and control sites. Pre-treatment data were collected in 2001 to establish baseline vegetation data for each study site. Vegetation also was sampled at each burrow used by a tortoise to compare habitat characteristics near burrows on firing points and in adjacent forest habitat and to determine whether changes in burrow usage might be associated with habitat changes near burrows as a result of burning. To determine how tortoises responded to the changes in habitat, yearly burrow surveys were conducted and adult tortoises were monitored by both radio-telemetry and powder tracking. Except for the vegetation transects, data collection began in 2002 and continued through 2004 (one-year post treatment).

The initial study design also included locating and protecting nests, documenting hatching success, and monitoring hatchlings. However, since no hatchlings were tracked in 2002 and 2003, the reproductive success and monitoring objective was terminated before 2004. Earlier nest/hatchling data are presented, but no statistical analyses were performed.

### 3 RESULTS

#### Habitat Changes

##### *Changes in Vegetation*

In 2001 transects were established at each study site. A random point was selected on the perimeter of the firing point and transects were located every 75 m from the starting point. Lines were drawn from these points extending into the forested area surrounding the firing point and sample points were generated every 25 meters along these lines (i.e., 25, 50, 75, 100, 125, 150, 175 m from firing point edge). Using the same azimuth as the line extending into the forest, we sampled at a location 25 m into the firing point. At each sample point, we positioned a 1-m<sup>2</sup> quadrat facing away from the firing point. We measured herbaceous heights at the bottom left and top right corners of the quadrat. We recorded percent cover of bare ground, litter, and vegetation by growth form categories (Total Herbaceous, Woody Vines and Shrubs, Graminoids-Grasses and Grass-like, Forbs, Legumes) and species using Peet's modified Daubenmire method (Peet et al. 1998). We counted stems of woody species within the quadrat and categorized them by diameter width. We measured basal area using a basal area prism. Each sample point was categorized by topographic position (upland, mesic slope, drain) and overall physiognomy (pine, hardwood, pine/hardwood mixed, herbaceous, other). Data were collected during May/June of 2001, 2002, 2003, and 2004.

Using the 2001 data, we calculated the percentage of sample points in each topographic and physiognomic category to determine whether management could possibly enhance gopher tortoise habitat in the areas surrounding the firing points. We also calculated percentage of sample points that were upland sites with greater than 25% herbaceous or grass cover as a rough estimate of the percentage of area that was likely already suitable gopher tortoise habitat.

Data collected in wetland plots or road plots were excluded from subsequent analyses. Mean values of measured variables were calculated for each firing point by each habitat type (firing point, adjacent forest) providing four replicates/treatment/habitat type. Analyses for each habitat type (firing point, adjacent forest) were performed to compare habitat variables for treatment and control sites measured in 2001 (pre-treatment) to ensure that sites were similar. We compared habitat of adjacent upland forest and firing points in 2001 by analyzing percent cover of woody and herbaceous vegetation using a randomized block

design with habitat type considered a treatment ( $n = 8$ ) and location a block (e.g., each firing point with its associated adjacent habitat). For the 2004 data we performed similar analyses, one for the burn treatment and one for the controls; therefore  $n = 4$  for each habitat type.

We used the SAS Proc Mixed procedure to perform a repeated measures analysis of variance to determine treatment (control; burn), year (2001, 2002, 2003, 2004), and interaction between treatment and year effects on measured variables except stem diameters in adjacent forested habitat. If analyses indicated significant effects by independent variables ( $p < 0.05$ ), additional analyses of variance were performed to examine differences between treatments within years and among years by treatment. For analyses examining treatment effects within years, 2001 data were added to the model as a covariate. To determine effects of burn treatments on densities of woody stems with diameters  $< 1$  cm in adjacent forested habitat, we performed analyses of variance for each year. Other categories of stem diameters were not analyzed because of low numbers encountered. We were unable to compare stem diameter changes across years due to a change in data collectors/methodology in 2004, thereby making comparison among years inappropriate.

Not unexpectedly, firing points were almost completely characterized as uplands with herbaceous cover (Fig. 3). The high percentage of upland/slope and pine/mixed physiognomic class (80%) indicated that management had the potential to enhance habitat for gopher tortoises in the adjacent forested areas. Of the variables measured within forested adjacent habitat, repeated measures analysis indicated an interaction ( $p < 0.05$ ) of treatment with year (i.e., there were differences in response between treatments within years) for percent cover of bare ground, litter, woody vegetation, herbaceous vegetation, forbs, and graminoids. Year was significant for herbaceous heights and percent cover of woody vegetation, herbaceous vegetation, and forbs. Additional analyses of variance indicate significantly less woody vegetation in 2003 and 2004 and significantly more herbaceous vegetation, forbs, and graminoids in 2004 on burned sites compared to control sites in adjacent forested habitat (Fig. 4 and 5). Although percent cover of woody vegetation on control sites in adjacent forested habitat remained fairly consistent throughout the study, percent cover of herbaceous vegetation, forbs, and graminoids decreased significantly from 2001 to 2004 (Fig. 6). Post-growing-season fire (2003), percent cover of woody vegetation was significantly reduced from 2001 levels in adjacent forested habitat on burned sites; however, by 2004 percent cover of woody vegetation had increased from 2003 levels and was similar to 2002 levels. Densities of woody stems  $< 1$ -cm diameter were comparable for burn and control sites in 2001 (means 5.7 stems/m burn sites; 6.1 stems/m control sites) in adjacent forest any year; but differences



between burn and control sites were marginally significant ( $p < 0.059$ ) by 2004 with burn sites averaging four stems/m more than control sites. Herbaceous variables measured in adjacent forested habitat on burned sites did not differ significantly among years. In 2001 adjacent forested habitat exhibited greater percent cover of woody vegetation and less percent cover of herbaceous vegetation than the firing points, and this pattern continued in 2004 regardless of burn treatment (Fig. 4 and 5).

Historically, the majority of the uplands and slopes of CSTS burned at frequent intervals, supporting open pine forests with a sparse midstory of scattered oaks and other hardwoods and a dense, bluestem-grass-dominated ground cover (Leonard et al. 1999). However, past fire exclusion and other management activities have resulted in higher tree basal areas, shrub and hardwood encroachment, and reduction of herbaceous forage in much of the forested areas on CSTS. Similar to our study, many studies have reported a decrease in woody biomass post-burning, but resprouting with multiple stems was also frequently documented (Boyer 1990, Streng et al. 1993). Glitzenstein et al. (1995) also did not obtain a rapid change in herbaceous ground cover after prescribed fire. This suggests that restoration of habitat may require more than reintroduction of fire and/or that restoration of habitat may be a more long-term process requiring increased frequency of fire for several years.

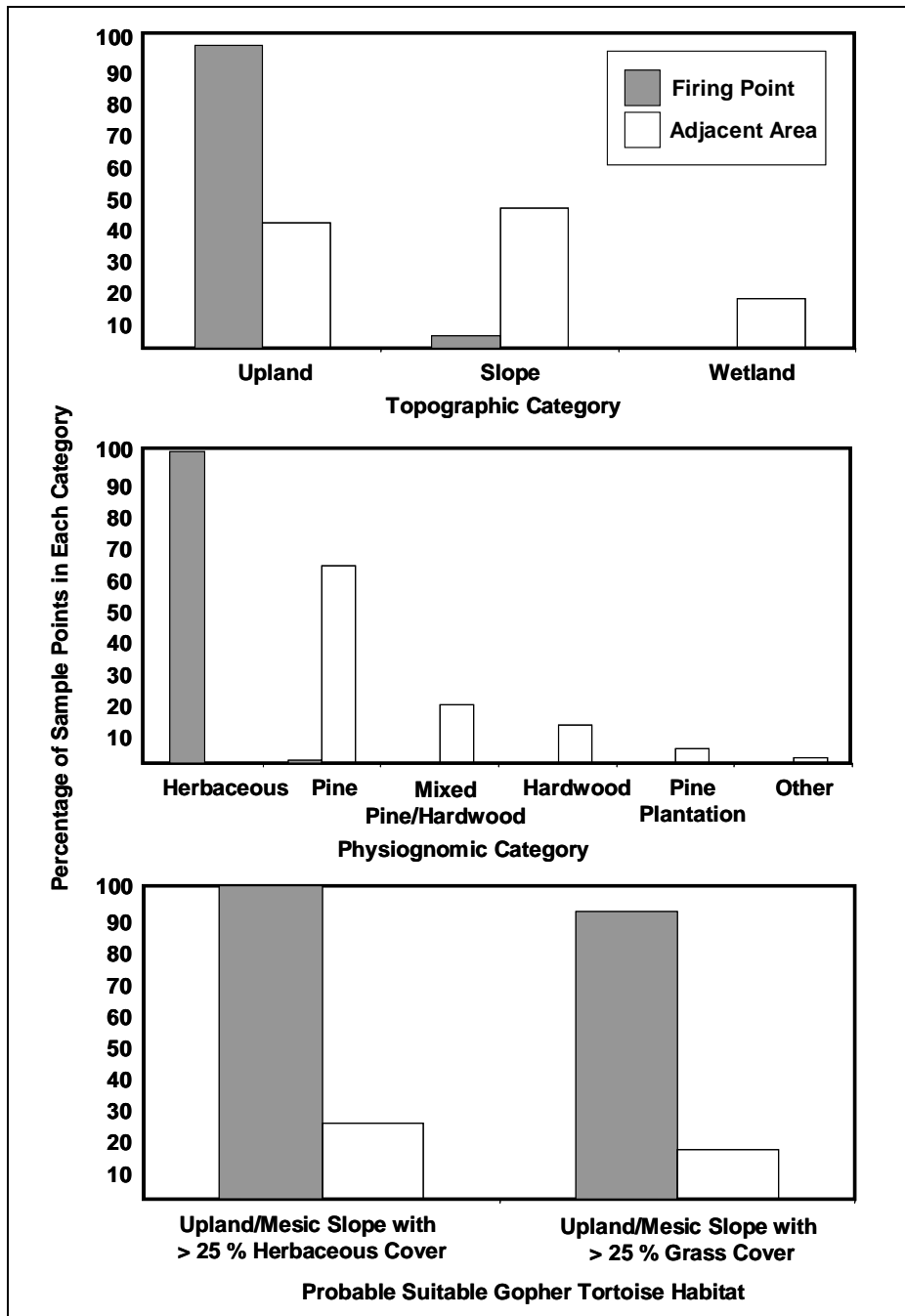


Figure 3. Percentage of sample points within each topographic and physiognomic category and percentage of sample points with probable suitable gopher tortoise habitat for eight firing points and their adjacent areas (200 m from firing point edge) sampled in May/June 2001 on Camp Shelby Training Site, Mississippi.

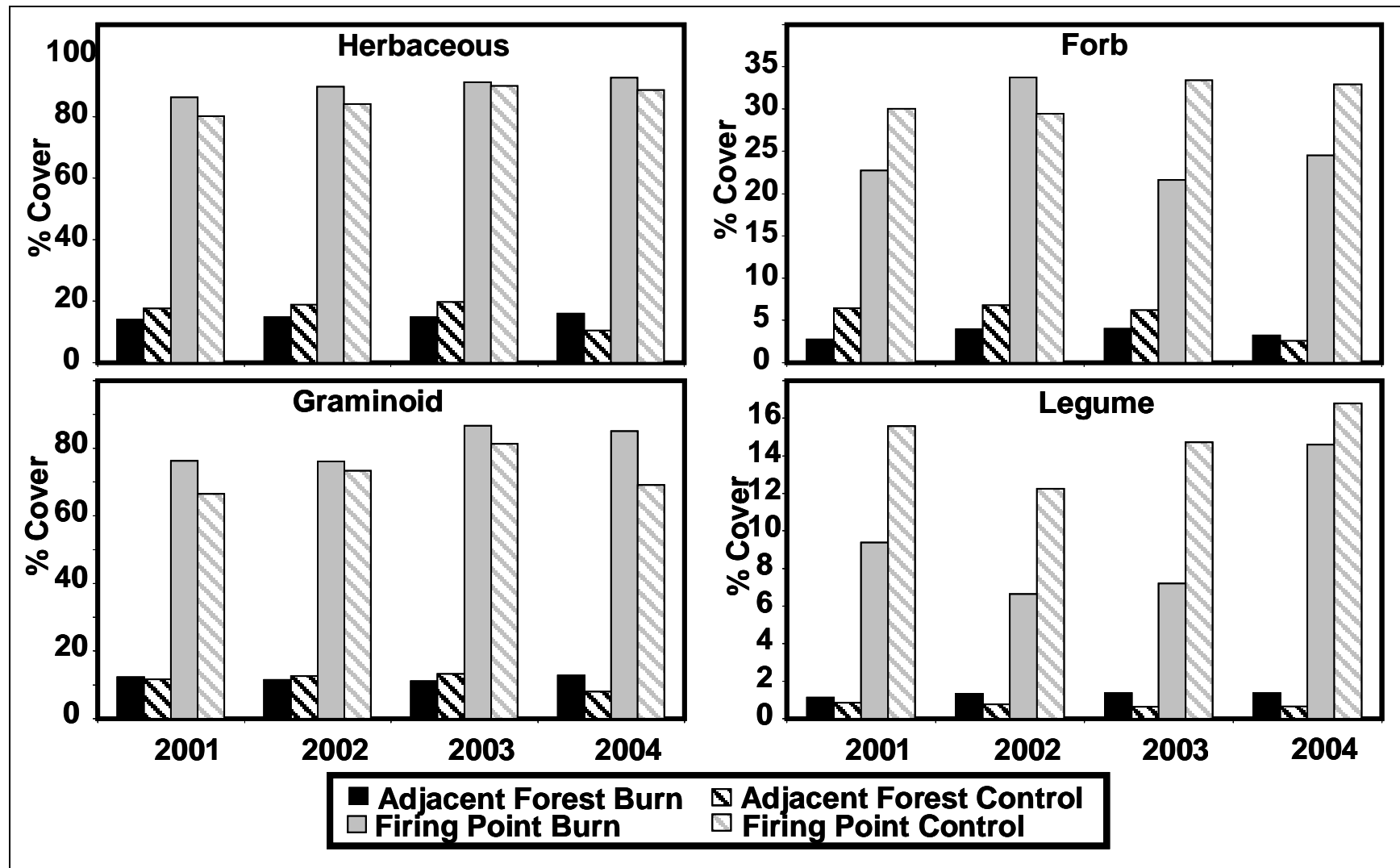


Figure 4. Percent cover of vegetation functional groups by habitat type (firing point, adjacent forest), burn treatment (dormant season burn–2002, growing season burn–2003), and year.

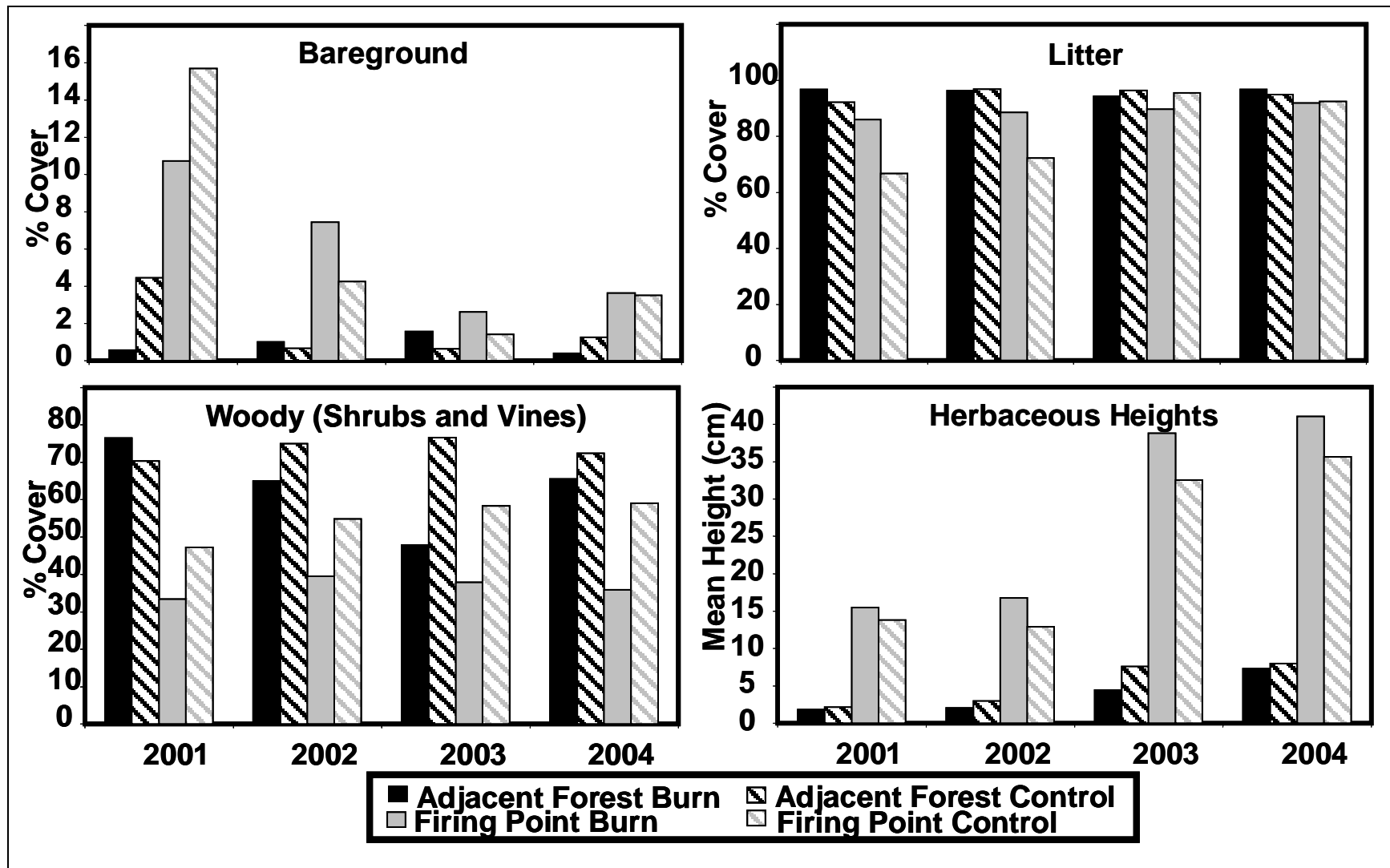


Figure 5. Percent cover of woody vegetation, bare ground, and litter and mean herbaceous heights by habitat type (firing point, adjacent forest), burn treatment (dormant season burn–2002, growing season burn–2003), and year.

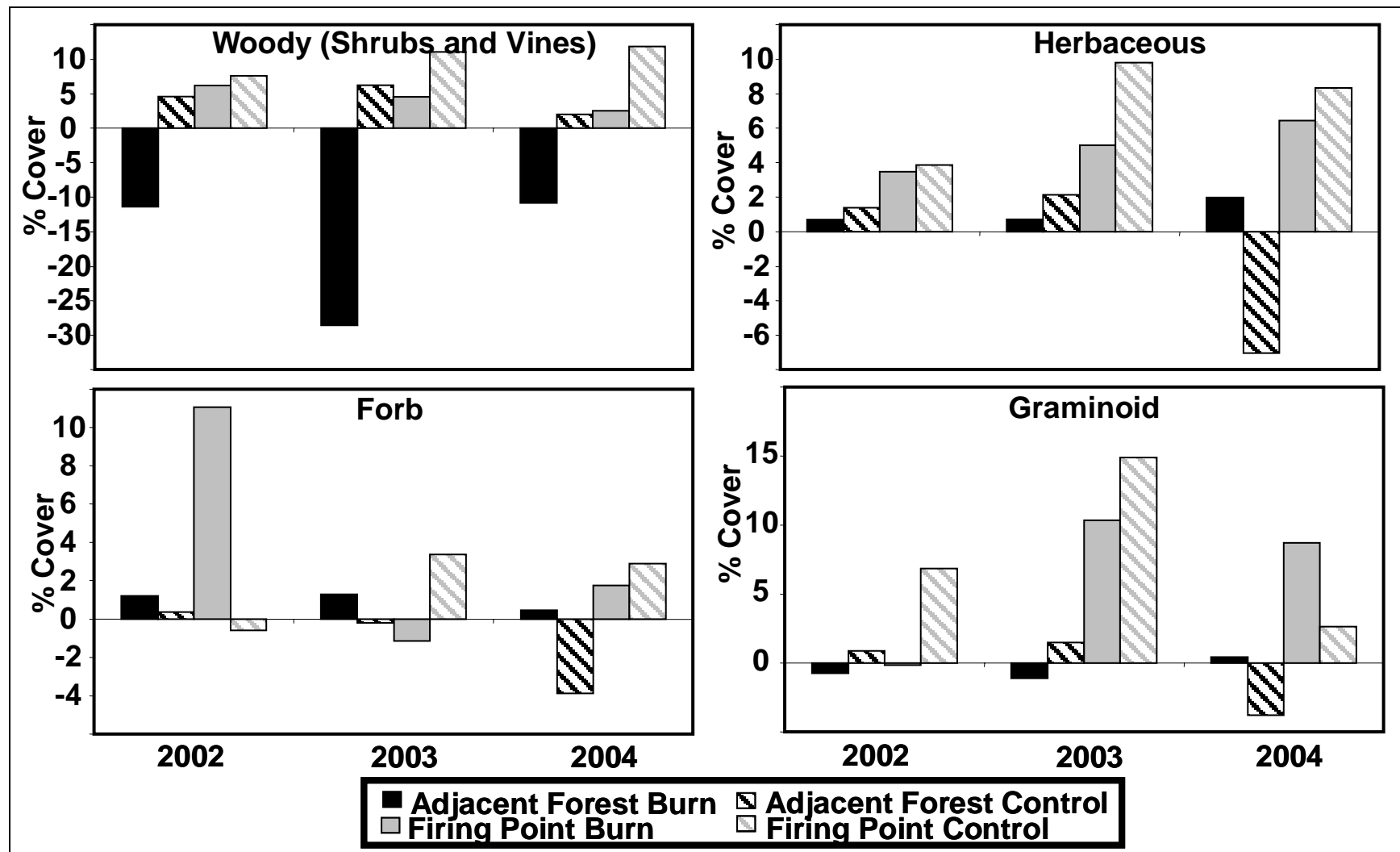


Figure 6. Change in percent cover of vegetation functional groups from 2001 by habitat type (firing point, adjacent forest), burn treatment (dormant season burn–2002, growing season burn–2003), and year.

### *Habitat Characteristics of Burrows*

We characterized vegetation around each burrow used by a radio-transmitted tortoise. Data were collected during June–September 2002, June–July 2003, and June 2004. We collected data on canopy cover, basal area, percent ground cover, herbaceous and shrub heights, and shrub stem count. Canopy cover was determined using a densiometer and basal area was calculated using a basal area prism. Percent cover was recorded using Peet's modified Daubenmire method (Peet et al. 1998) and was classified using the following categories: total herbaceous, graminoids, forbs, legumes, woody/vines, shrubs, leaf litter, and bare ground. Five 1-m<sup>2</sup> quadrats (0.5 m behind, 1 m left, 1 m right, and 0.5 m and 3 m in front of burrow) were used to collect percent ground cover. Herbaceous and shrub heights were measured at the corners of each quadrat. Shrub stems were counted within a 2.5-m radius and were classified according to diameter width. Because the quadrats placed 0.5 m in front of burrows were composed mainly of burrow aprons and had different amounts and types of ground cover, they were excluded from these analyses. We used an SAS general linear model to perform analyses of variance to determine effects of time (2002, 2003, 2004), treatment (burned, control), habitat type (firing point, adjacent forest), and the interactions among these factors on vegetation cover by functional group and tree basal area near burrows.

Herbaceous, forb, graminoid, and leguminous cover were significantly greater near burrows on firing points compared to adjacent forest for all three years (Fig. 7). For these variables, there was significant variation among years, but burn treatment was not significant. Canopy cover was significantly greater than in adjacent forest (84, 84, and 61% for 2002, 2003, and 2004, respectively) compared to firing points (20, 7, and 4% for 2002, 2003, and 2004, respectively). Basal area was also greater in adjacent forest compared to firing points. Although percent cover of shrubs was generally higher near burrows in adjacent forest compared to firing points, post-growing season burn (2003) shrub cover was reduced near burrows in adjacent forest (Fig. 8). However, by 2004, shrub cover was similar near burrows for burned or control in adjacent forests.

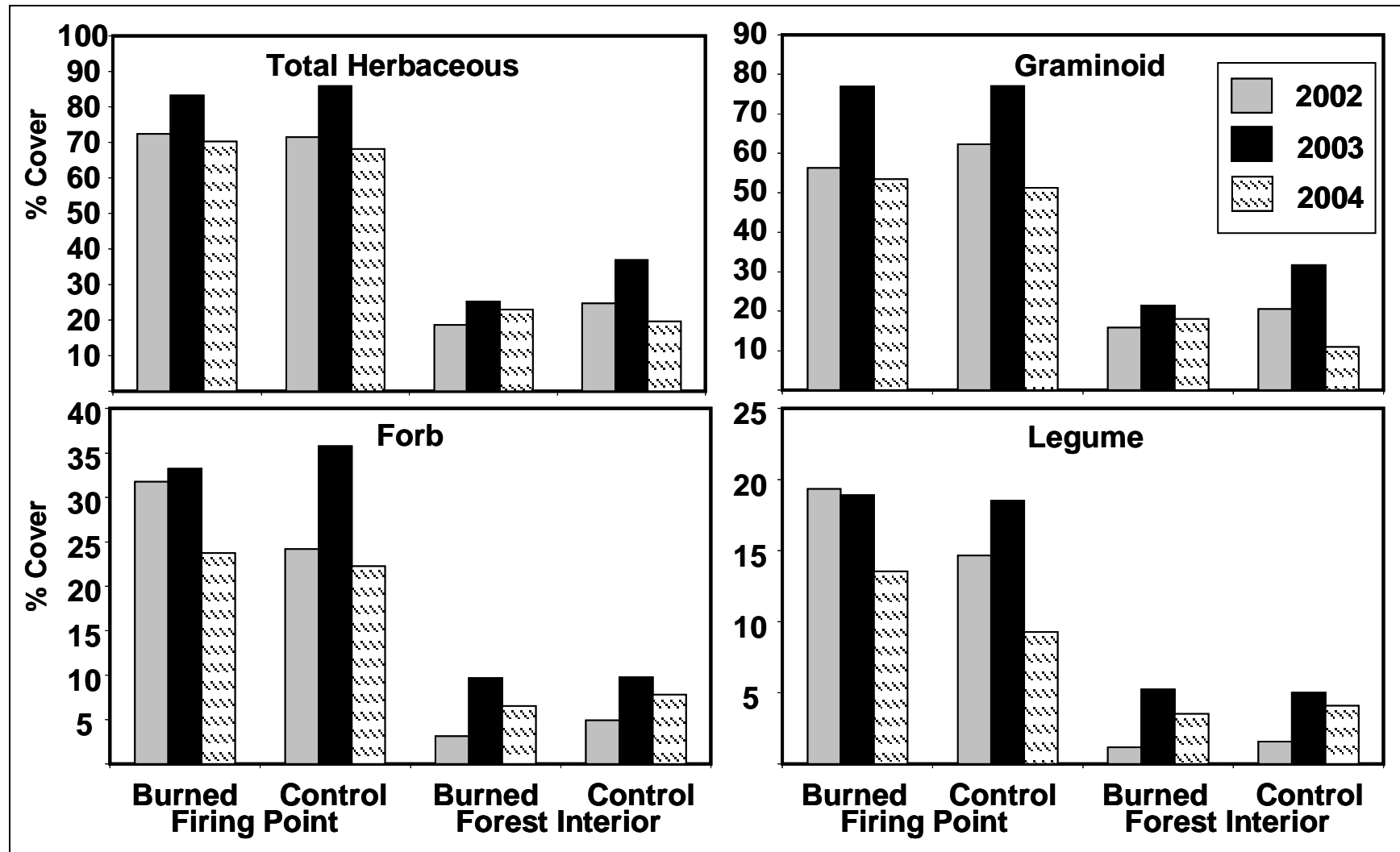


Figure 7. Percent cover of herbaceous vegetation on burned sites (dormant season burn–2002, growing season burn–2003) and unburned sites on firing points and in adjacent forest interior by year.

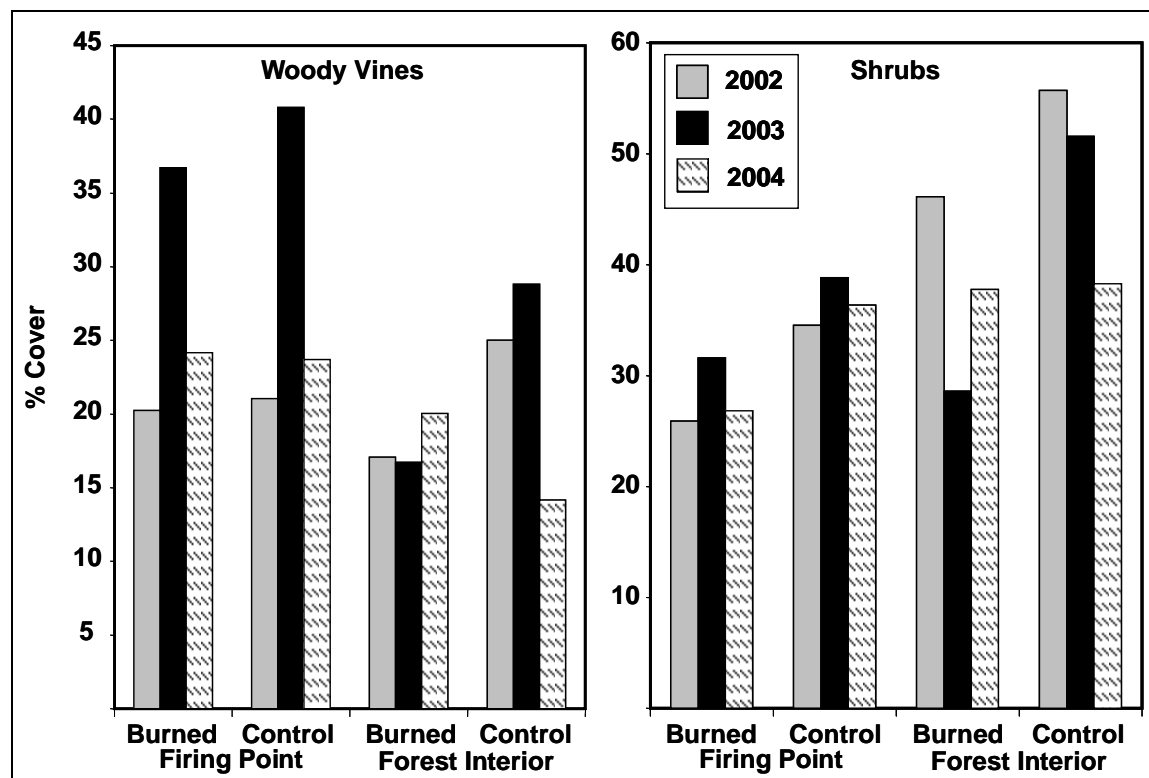


Figure 8. Percent cover of woody vines and shrubs on burned sites (dormant season burn–2002, growing season burn–2003), and unburned sites on firing points and in adjacent forest interior by year.

### Tortoise Activity and Abundance

#### *Burrow Surveys*

Study sites were surveyed for gopher tortoise burrows in April 2002, 2003, and 2004. All burrows were subjectively classified by activity status into one of three categories: active, inactive, or old (abandoned). Also, burrows were classified as forest interior, firing point, or forest edge. If a burrow entrance was within five meters of the firing point perimeter, it was designated as a forest edge burrow. Survey results for 2002 and 2004 were compared to see whether any shifts could be determined in numbers or activity levels of burrows. There were 158 burrows located in the initial survey in 2002 (154 adult burrows) and 188 burrows located in the 2004 survey (187 adult burrows). A summary of burrow numbers, with percentage increases by treatment and burrow type, can be found in Table 1. Active and inactive burrows were combined to represent activity since both designations describe burrows that have been recently maintained (Auffenberg and Franz 1982). Noteworthy increases in activity level were at



forested burrows on burned sites and at firing point burrows on control sites. In 2002, 11 of the 16 forest interior burrows on burned sites were considered active (68.8%), and 28 of the 53 firing point burrows on control sites were considered active (52.8%). However, results of the surveys in 2004 showed that 30 of the 31 forest interior burrows on burned sites were considered active (96.8%), and 45 of the 57 firing point burrows on control sites were considered active (78.9%). These increases (28.0% and 26.1%, respectively) were the largest increases in percent activity of all the burrow types.

In addition to the new burrows discovered during surveys, there were nine burrows discovered between April 2004 and the end of the study. Of these 42 new burrows identified after the 2002 survey, the number of firing point burrows found was similar between burned and control sites (seven and six, respectively); however, the number of forest interior burrows found was twice as great at burned sites than at control sites (18 and nine, respectively).

**Table 1. Results from burrow surveys in 2002 and 2004.\***

	# of burrows from 2002 survey	# of burrows from 2004 survey	increase in # (2002 to 2004)	% increase (2002 to 2004)
total	154	187	33	21.4%
burned sites	69	89	20	29.0%
control sites	85	98	13	15.3%
burned sites (A + I)	49	80	31	63.3%
control sites (A + I)	49	80	31	63.3%
FP on burned sites	50	54	4	8.0%
FI on burned sites	16	31	15	93.8%
FE on burned sites	3	4	1	33.3%
FP on control sites	53	57	4	7.5%
FI on control sites	17	25	8	47.1%
FE on control sites	15	16	1	6.7%
FP on burned sites (A + I)	37	48	11	29.7%
FI on burned sites (A + I)	11	30	19	172.7%
FE on burned sites (A + I)	1	2	1	100.0%
FP on control sites (A + I)	28	45	17	60.7%
FI on control sites (A + I)	14	22	8	57.1%
FE on control sites (A + I)	7	13	6	85.7%
* Numbers are from adult burrows only. (FP = firing point burrows, FI = forest interior burrows, FE = forest edge burrows, A + I = active + inactive burrows)				

### *Movement of Adult Gopher Tortoises*

**Radio-tracking.** Radio-transmitters were affixed with epoxy to 44 gopher tortoises in the first year of the study (2002), and one more was added in 2003. Each study site originally had four to seven tortoises that were tracked. Because of issues with transmitter attachment and malfunction, several signals were lost. In 2003, 14 failing transmitters were replaced, and 10 were replaced in 2004. Tortoises were located twice per week during the active season (April–October) and once per week during the dormant season, for a total of 6024 tracking locations. Of these, only six represented instances when an individual was found above ground and did not immediately move into a nearby burrow. Tortoise locations were assigned to the GPS coordinates of the burrow that they inhabited, regardless of their location inside the burrow.

One tortoise had a signal that was lost after nine days, and this individual's data were removed from all analyses. Data from the remaining 44 tortoises were used to compare numbers of movements, movement distances, and burrows used between sexes and treatments (Table 2 shows the sex ratios at each of the firing points). Of these 44, there were 40 individuals that were tracked for more than 300 days, and only data from these were used to compare home range between sexes and treatments. All comparison analyses were performed using ANOVA (unless otherwise noted); significance for all analyses in this study was determined by  $p$ -values  $\leq 0.05$ .

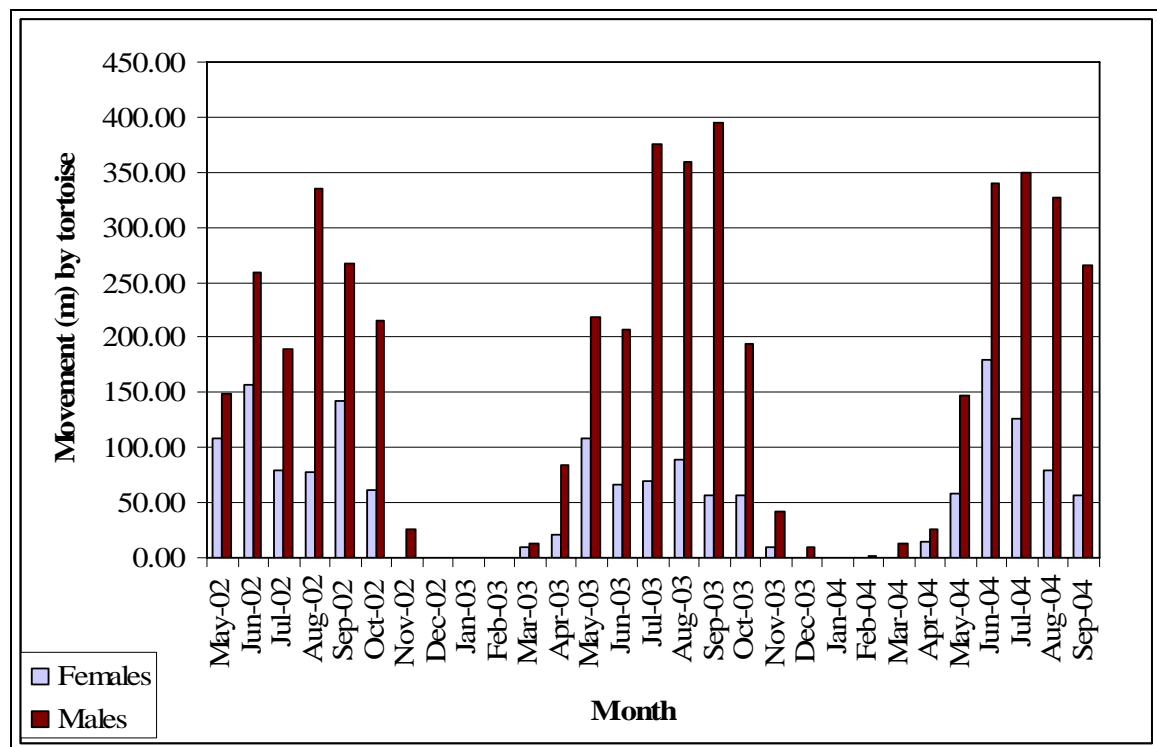
**Table 2. Sex ratios at each of the study sites.**

	Burned sites				Control sites			
Firing point #	140	136	65	79	68	91	127	83
Ratio (M:F)*	4:2	2:2	4:3	3:3	5:2	1:4	2:3	2:2
* Ratio (M:F) of total population = 23:21, burned sites = 13:10, control = 10:11								

**Movement summary.** Tortoises were tracked for a total of 27,840 days, an average of 696 days per individual. Total length of the study was 895 days. The number of movements was significantly different for males than females ( $p < 0.001$ ); on average, males (mean  $\pm$  SD =  $29 \pm 7$  times) changed burrows more than females ( $8 \pm 3$  times). Extremes in numbers of movements ranged from a female that moved eight times in 650 days to a male that moved 82 times in 758 days. No significant difference was found in number of movements between control and treatment groups.

Estimation of total distance moved was solely based on straight-line movements between burrows, and should therefore be taken as a conservative estimate.

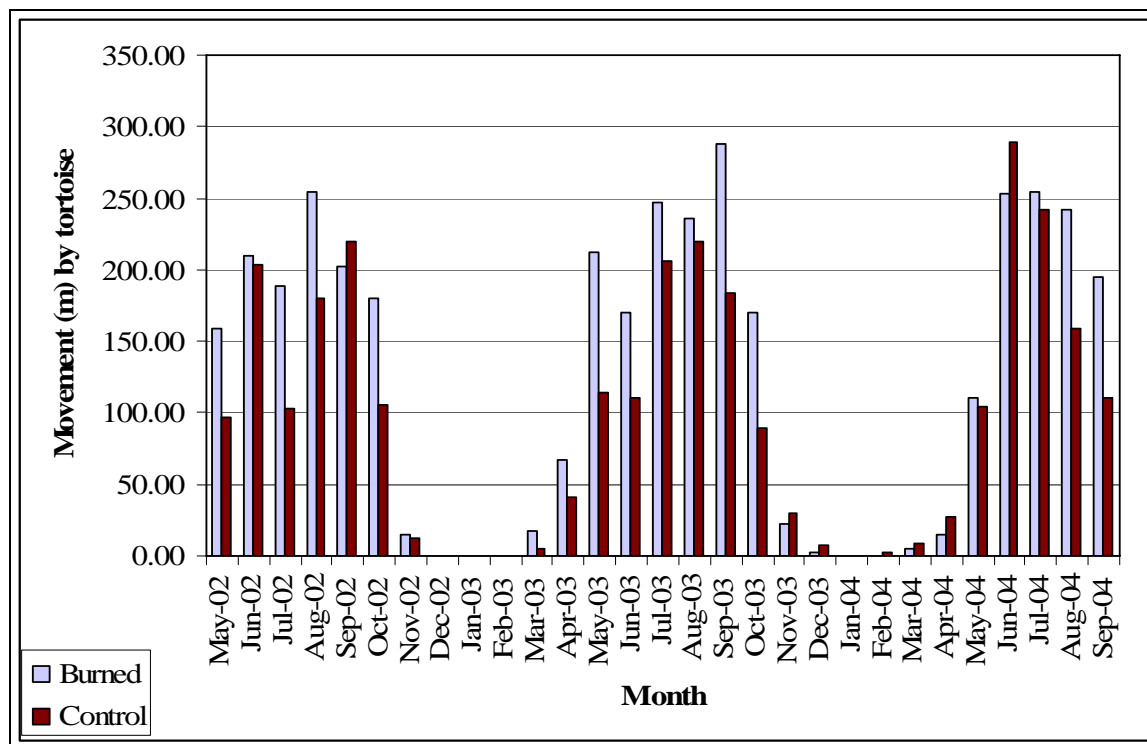
Total distance moved was also significantly different for males than females ( $p < 0.001$ ); males moved farther ( $3765 \pm 2154$  meters) than females ( $1188 \pm 629$  meters) over the course of the study. Extremes in total distance traveled ranged from a female that moved a total of 369 meters in 650 days to a male that moved over 10,500 meters in 755 days. There was no significant difference in distance traveled between control and treatment sites. Total monthly movements by sex and treatment are shown in Figures 9 and 10.



**Figure 9. Average monthly movements by sex for a population of 44 gopher tortoises.**

Movements also were categorized by the type of burrow the tortoise was leaving and the type of burrow to which the tortoise was moving (e.g., firing point to forest interior). This was done to see whether there were certain times of the year that tortoises tended to move into forested areas, and/or certain times of the year that they tended to move back onto firing points. These two types of movements were summarized to look for trends by month and by treatment. No differences were found between these specific types of movements and the general movement trends shown in Fig. 10. In other words, the frequency of both of these types of movements increased in the spring, peaked in the summer, and then gradually decreased again in the fall. The average distance tortoises moved

each month was highly correlated with average monthly temperature (see Fig. 11; Adj.  $R^2 = 0.83$ ,  $p < 0.001$ ).

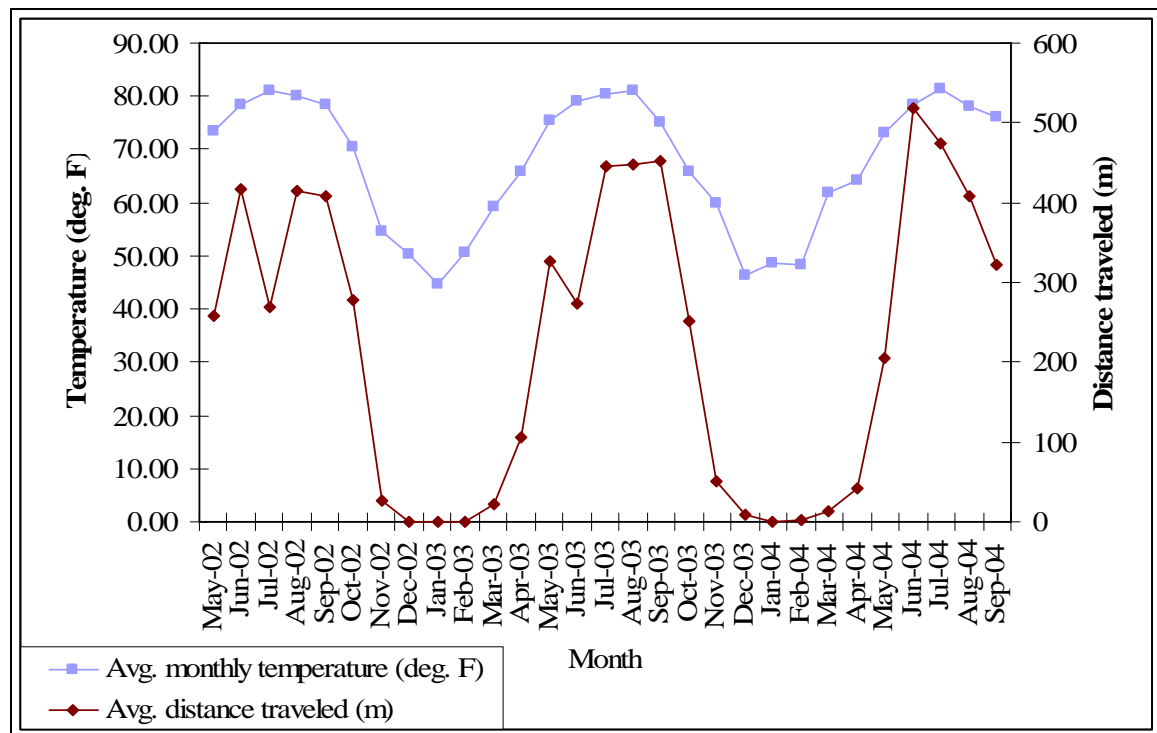


**Figure 10. Average monthly movements by treatment for a population of 44 gopher tortoises.**

**Burrow use.** Before estimating the average time a tortoise spent at a burrow, the overwintering period data were first removed, leaving only active season tracking data in the calculation. For the purpose of this study, overwintering was defined as the total time a tortoise stayed in the burrow where it spent the winter, and was analyzed separately from active season burrow use data. The average time spent at a burrow differed significantly by sex ( $p < 0.001$ ), and neared significance by burn status ( $p = 0.14$ ). Males spent less time at each burrow ( $9 \pm 4$  days) than females ( $22 \pm 8$  days) during the active season, and tortoises at burned sites spent less time at each burrow ( $14 \pm 8$  days) than tortoises at control sites ( $18 \pm 10$  days) during the active season. Total times that burrow types were occupied during the active season are shown in Table 3.

Tortoises used an average of 9.3 burrows over the course of the study, and number of burrows used was significantly higher ( $p < 0.001$ ) in males ( $11.5 \pm 4$ ) than in females ( $7.2 \pm 2.3$ ). The difference in number of burrows used also ap-

proached significance between treatments ( $p = 0.13$ ); tortoises on burned sites used  $10.3 (\pm 3.9)$  burrows, and tortoises on control sites used  $8.4 (\pm 3.7)$  burrows. Extremes in numbers of burrows used were a female that occupied only four different burrows in 650 days, and a male that occupied 15 different burrows in 406 days.



**Figure 11. Average monthly temperature ( $^{\circ}\text{F}$ ) and average distance traveled by month for a population of 44 gopher tortoises. Weather data are from Hattiesburg Airport (HBG), ~20 km NW of Camp Shelby (Weather Underground 2004).**

<b>Table 3. Total amount of time gopher tortoises spent in each type of burrow, total numbers of each type of burrow used, and average number of days spent in each burrow (by sex and by treatment). Data are from active season only.</b>				
	<b>Burrow type</b>	<b># of days spent in burrows</b>	<b># of burrows used</b>	<b># of days/burrow</b>
<b>Treatment</b>				
Burned	Firing point	5486	51	107.6
	Forest edge	69	1	69.0
	Forest interior	1771	27	65.6
Control	Firing point	4356	43	101.3
	Forest edge	1073	12	89.4
	Forest interior	1702	29	58.7
<b>Sex</b>				
Females	Firing point	3472	64	54.3
	Forest edge	481	8	60.1
	Forest interior	2029	34	59.7
Males	Firing point	6370	85	74.9
	Forest edge	661	12	55.1
	Forest interior	1444	35	41.3

**Overwintering.** Average overwintering period during this study was 200 days ( $\pm 48$  days), and differed significantly between males and females. Females overwintered for a longer time ( $229 \pm 39$  days) than males ( $171 \pm 37$  days); the shortest amount of time a tortoise overwintered was 81 days (by a male), and the longest was 370 days (by a female). Although this latter tortoise was probably active for part of this time, it would be impossible to tell what the true date of emergence was. There were 25 instances during this study when a tortoise remained in the same burrow for more than 210 consecutive days, and 23 of those times the tortoise was a female. The average onset date of overwintering was October 10th ( $\pm 31$  days), and the average emergence date was April 28th ( $\pm 29$  days). There was no significant difference in overwintering duration between control and treatment sites.

Tortoises overwintered 69 times over the course of this study. On burned sites, 84% used firing point burrows, 16% used forest interior burrows, and none used forest edge burrows. On control sites, 59% used firing point burrows, 27% used forest interior burrows, and 14% used forest edge burrows. There was one

instance each winter when two tortoises overwintered in the same burrow; it was the same burrow both years (a firing point burrow on a burned site), but different tortoises each year.

**Home range.** For estimation of home range, the 95% kernel estimate with smoothing selected by least-squares cross-validation (LSCV) was used. This estimate provides accurate results with low bias and low surface fit error, providing there are at least 50 observations per animal (Seaman et al. 1999, Seaman and Powell 1996, Worton 1989). All of the 40 tortoises tracked for over 300 days were tracked > 70 times per year. Although estimates of home range using the Minimum Convex Polygon (MCP) method were not used in any analyses for this project, they were still reported because studies of other populations of gopher tortoises may estimate home range this way (see Table 4). The 100% MCP method was used instead of the 95% MCP because females used an average of only ~7 burrows during the study while males used an average of ~12. Therefore the 95% MCP method would remove at least one burrow location from the home range estimations of males, but would not remove any burrow locations from most of the females' estimations.

**Table 4. Home range estimates of gopher tortoises from Camp Shelby, Mississippi: minimum tracking period of 300 days.**

	n	100% MCP* (ha)		95% kernel (ha)	
		Mean $\pm$ SD	Range	Mean $\pm$ SD	Range
All tortoises	40	1.59 $\pm$ 1.57	0.11–7.65	1.09 $\pm$ 1.25	0.05–6.55
Females (all)	20	1.53 $\pm$ 1.78	0.11–7.65	1.30 $\pm$ 1.65	0.05–6.55
Males (all)	20	1.66 $\pm$ 1.38	0.63–4.89	0.88 $\pm$ 0.63	0.23–2.73
Burned sites	20	1.56 $\pm$ 1.48	0.11–4.89	1.02 $\pm$ 0.71	0.09–2.73
Control sites	20	1.63 $\pm$ 1.70	0.21–7.65	1.16 $\pm$ 1.64	0.05–6.55
Females (burned sites)	9	1.07 $\pm$ 0.86	0.11–2.46	0.98 $\pm$ 0.64	0.09–2.18
Females (control sites)	11	1.90 $\pm$ 2.25	0.21–7.65	1.57 $\pm$ 2.17	0.05–6.55
Males (burned sites)	11	1.95 $\pm$ 1.79	0.63–4.89	1.05 $\pm$ 0.80	0.23–2.73
Males (control sites)	9	1.30 $\pm$ 0.52	0.71–2.43	0.67 $\pm$ 0.25	0.33–1.10
* MCP = Minimum Convex Polygon					

Home range was not significantly different between sexes ( $p = 0.29$ ), between control and treatment sites ( $p = 0.73$ ), or in the interaction between sex and treatment type ( $p = 0.23$ ). Females had a larger average home range than males; however, if the two largest home ranges (6.55 ha and 4.99 ha, both

females) were removed from calculations, the average home range of females became less than males ( $0.81 \pm 0.61$  ha). A Tukey HSD Multiple Comparison test showed that there were no significant differences in home range size from pairwise comparisons among the eight firing points ( $p = 0.19$ ). Also, a linear regression analysis determined that there was no association between home range size and the number of days tracked (Adj.  $R^2 = 0.02$ ;  $p = 0.43$ ).

Average home range sizes found in this study were comparable to those found in other studies (see Table 5). However, maximum home ranges were higher than previously reported. Douglass (1976) reported home ranges of two males in Florida to be 4.2 and 6.3 ha in studies over five years long, and Eubanks et al. (2003) reported maximum annual home ranges from a study in Georgia to be 3.4 ha for females and 4.8 ha for males. The female with the 7.65-ha home range in this study was tracked for 372 days, and this represents the largest annual home range reported in any gopher tortoise study.

<b>Table 5. Mean home range sizes (MCP) from this and other studies.</b>			
<b>Home range</b>		<b>State</b>	<b>Study</b>
<b>Females</b>	<b>Males</b>		
0.08	0.44	Georgia	McRae et al. 1981
0.06	1.05	Florida	McLaughlin 1990
0.31	0.88	Florida	Diemer 1992
0.38	n/a	Florida	Smith 1995
0.65	1.92	Florida	Smith et al. 1997
0.40	1.10	Georgia	Eubanks et al. 2003
1.53	1.66	Mississippi	Present study

**Comparisons between field seasons.** There were 23 tortoises that were tracked for over two years, and separate analyses were done on these comparing data between the first and second field seasons. For each tortoise used in these analyses, the first day of its first field season began between May and August 2002, with the first day of its second field season beginning on the same day in 2003. This start date was staggered over the summer since radio-tracking did not always start at the same time. However, all first field seasons began after the dormant season burns in the winter of 2001/2002, and all second field seasons began after the growing season burns in April 2003.

On average, home range increased in size from the first year to the second year, but this increase was highly variable ( $51 \pm 147\%$ ). The only subset of



individuals that showed a decrease in the second year was the males on burned firing points. Using a repeated measures analysis test, home range did not increase significantly by sex ( $p = 0.57$ ) or by treatment ( $p = 0.89$ ) from the first year to the second year.

Several other repeated measures analyses were performed by sex, by site, and by treatment, comparing data between first and second years. No significant differences were found in percentage of time spent in forested burrows, total distance traveled, numbers of movements, or numbers of burrows used. These analyses were performed on active season data only, since overwintering data accounted for a large percentage of the tracking time for many individuals, and was examined as a separate behavioral season. There were no significant differences found by sex or by treatment in which type of burrow was used for overwintering; typically the type of burrow a tortoise used during the winter was the same for both years. There were six tortoises that utilized the same overwintering burrow two years in a row, and these six included individuals of both sexes and both treatment types. The only tortoise that overwintered in a firing point burrow the first year and a forested burrow the second year was a female on a control site, and there were three other females (on both control and burned sites) that overwintered in a forested burrow the first winter and a firing point burrow the second.

**Powder tracking.** We used powder tracking to examine daily movement patterns of gopher tortoises on the study sites. Although radio-tracking is appropriate for determining large-scale movement patterns and home ranges, radio-tracked gopher tortoises were almost always found in burrows. Powder tracking was utilized to get a better understanding of microhabitat use (e.g., habitat used for foraging), and to help determine small-scale movement patterns.

The protocol in Blankenship et al. (1990) was followed for powder tracking tortoises. Small bags filled with fluorescent powder (Radiant Color) were first fashioned out of panty hose. A small hole was drilled in the 12th marginal scute of each tortoise, and the bag was tied to the tortoise through this hole with embroidery thread. The length of the thread was adjusted so that the powder bag dragged on the ground behind the tortoise as it walked (Fig. 12). Tortoises were released at the burrow where they were captured, and then were tracked every night either until it was no longer possible to follow their powder trail or until at least three daily trails were determined. Handheld ultraviolet lights were used at night to follow the fluorescent powder trails, and trails were marked with survey flags (Fig. 13). These trails were then mapped in the following days with GPS. It was not possible to follow the trails of some tortoises due to excessive rain or

powder bags falling off, or if they remained inside a burrow for more than a week.



**Figure 12. Gopher tortoise with powder bag attached.**





**Figure 13. Powder tracking trail marked with survey flags. Burrows are marked with posted yellow signs.**

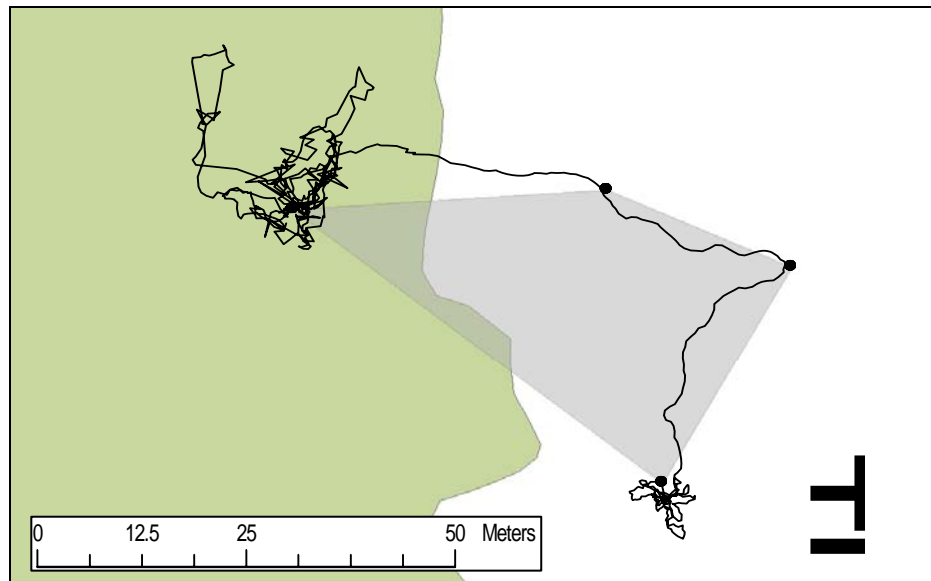
Tortoises were tracked at two different time periods each year: from late April to early May, and from late July to mid-September. All tortoises were tracked between one and five days, and typically after two or three days the powder trails became indiscernible either because there was a large amount of powder on the ground or because the bags had run low on powder and the trails became faint. By overlaying the mapped trails onto maps of firing points using GIS, the number of trails that were in forested cover at some point was determined. Table 6 summarizes the powder tracking trails found for all three years. Approximately the same number of trails was found each year, and each year a smaller percentage of trails at burned sites was found in forested cover than at control sites. No trends were observed for either treatment over the three years, and the highest percentage of trails that entered forested cover at some point was found on control sites in 2003 (52.6%). Lengths of powder tracking trails were not compared, since movement analyses were already performed using long-term radio-tracking data. Also, on several occasions there were enormous distances

traveled the day the tortoise was released, possibly resulting from the experience of being trapped and handled. Since individuals may react differently to these anthropogenic stresses, a comparison of powder trail lengths may inaccurately reveal differences between treatments.

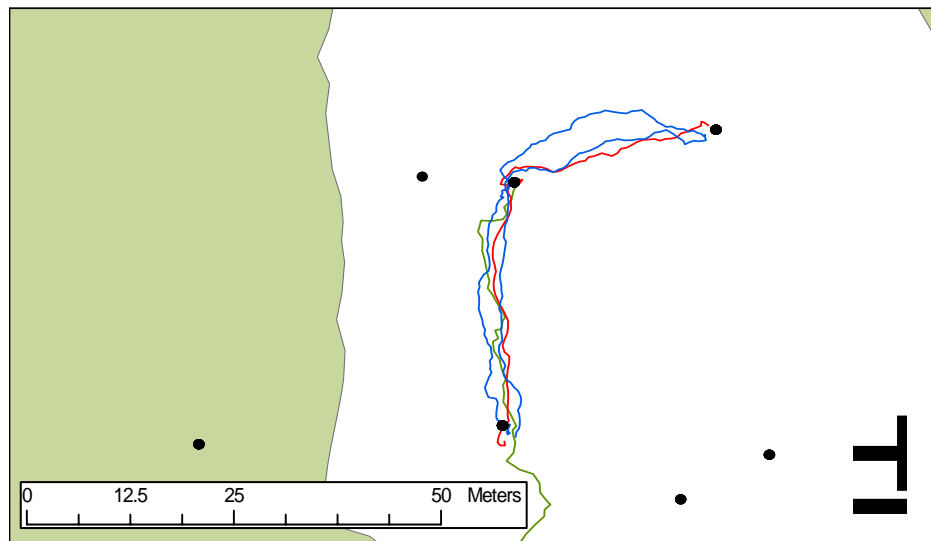
<b>Table 6. Summary of powder tracking trails for gopher tortoises on Camp Shelby, Mississippi. A trail was counted as "in forest" if any segment of it was located outside the perimeter of the firing point.</b>				
		<b>2002</b>	<b>2003</b>	<b>2004</b>
All sites	# trails total	80	75	85
	# trails in forest	26	28	26
	<b>% of total</b>	<b>32.5%</b>	<b>37.3%</b>	<b>30.6%</b>
Burned sites	# trails total	41	37	41
	# trails in forest	12	8	10
	<b>% of total</b>	<b>29.3%</b>	<b>21.6%</b>	<b>24.4%</b>
Control sites	# trails total	39	38	44
	# trails in forest	14	20	16
	<b>% of total</b>	<b>35.9%</b>	<b>52.6%</b>	<b>36.4%</b>

Although most of the powder tracking trails were located within the MCP home range of the tortoise, several trails were far enough outside the home range polygon to considerably increase its size (see Fig. 14). These increases were not analyzed statistically since the 95% kernel method was used to estimate home range size; however, these powder tracking data illustrate one of the issues with the MCP estimation. Because our radio-tracking data captured locations of tortoises only when they were in burrows, there was the potential to miss documenting some of the surrounding habitat used during daily movements.

Some tortoises also demonstrated similar movement patterns when powder tracking trails from all three years were examined together. Figure 15 illustrates similar movement trails by the same tortoise over several years, an observation that helps understand that gopher tortoises may typically follow well-established movement trails and patterns.



**Figure 14.** Three years of powder tracking trails (in black) and 100% MCP home range (gray-shaded area) of a gopher tortoise on a control site. The green area represents the forested area around the firing point. Black dots represent burrows.



**Figure 15.** Three years of powder tracking trails by a gopher tortoise on a control site. The green trail is from 9/5/02, the red trail is from 8/26/03, and the blue trail is from 5/7/04. The green area represents the forested area around the firing point. Black dots represent burrows.

**Reproduction.** For the first two years of the study, nest searches were conducted at all of our study sites during the tortoise nesting period (mid-May through the end of June). Although gopher tortoises may occasionally dig nests in disturbed sites several meters away from burrows, tortoises at Camp Shelby typically lay their eggs in burrow aprons (Epperson and Heise 2003). For this reason, nest searches were concentrated on the aprons, and all of the burrows were visited three times per week at two- to three-day intervals. Nests were searched by probing the soil in a burrow apron to feel for eggs. When nests were found, the eggs were counted and nest cavity measurements were taken. The eggs were then replaced and covered over, and a mesh nest protector cage was set up over the area. During the hatching period, nests were checked every day to determine when hatchlings emerged.

Ten gopher tortoise nests were located on the study sites in both 2002 and 2003. Similar ratios of nests discovered on control and burned sites were found each year: in 2002 the ratio of burned to control site nests was 4:6, and in 2003 it was 5:5. Each year there were eight nests located on firing points, and the other two in forest edge or forest interior locations. In 2002 the nests found off of the firing point were at control sites, and in 2003 the two nests were at burned sites. Nests were located from 5/17/02 to 6/27/02, and from 5/15/03 to 6/9/03. These nesting periods are similar to those found in studies from other years (Epperson and Heise 2003). Clutch sizes by treatment and by year are summarized in Table 7. Although average clutch sizes were consistently larger at control sites, clutch size was not found to be significantly different by treatment ( $p = 0.52$ ).

**Table 7. Summary of average numbers of eggs/clutch from nest searches performed in 2002 and 2003. Data are presented  $\pm$  one standard deviation. Average clutch size on Camp Shelby has been reported as  $4.82 \pm 1.85$  eggs/nest (Epperson and Heise 2003).**

	2002 (n = 10)	2003 (n = 10)	Total (n = 20)
All	$4.20 \pm 1.55$	$4.10 \pm 1.73$	$4.15 \pm 1.60$
Burned sites	$4.00 \pm 1.41$	$3.80 \pm 2.39$	$3.89 \pm 1.90$
Control sites	$4.33 \pm 1.75$	$4.40 \pm 0.89$	$4.36 \pm 1.36$

No hatchlings emerged from nests in 2002, and only one hatchling emerged from a nest in 2003. This hatchling was in a forested area on a burned site, and was found preyed upon by red imported fire ants (*Solenopsis invicta*). Predation by red imported fire ants was believed to have begun before the hatchling fully emerged from the nest. Analysis of the remaining unbroken eggs excavated from the nest cavities found that only 22 of 77 showed any signs of development.

The hatching success documented in this study is much lower than what is typically reported in other studies. A concurrent study in southern Mississippi documented hatching success rates at predator-protected nests of 8% ( $n = 17$ ), 17% ( $n = 17$ ), and 56% ( $n = 7$ ) for 2002, 2003, and 2004, respectively (Noel 2005). A possible reason for the low hatching success in this study is because of the large amount of rain during the incubation periods of 2002 and 2003. Because the soils in Mississippi contain more loamy material and are less sandy than soils in other parts of the tortoise's range, it is possible that water may not drain away from the eggs quickly enough, thereby suffocating the developing embryos. Because of the low hatching success in 2002 and 2003, the reproductive success objective of this study was terminated in 2004.

### Summary

The pretreatment vegetation data indicated that some of the forested areas (24%) were already suitable gopher tortoise habitat and that much of the forested areas (80%) had the potential to be improved. Initial observations were that many tortoises were already using forested areas, but that there was much more activity on the ruderal firing points. In general, forested areas with minimal herbaceous ground cover and a well-developed woody midstory will provide insufficient forage and/or inadequate nesting conditions for gopher tortoises. Percent cover was much lower for herbaceous vegetation (all functional groups) and higher for midstory woody vegetation in adjacent forested habitats compared to firing points throughout the study.

Although percent cover of woody vegetation was decreased by the combined dormant and growing season burns in the adjacent habitat in 2003, herbaceous vegetation was not increased in 2003 or 2004. Further, the increase of stem densities on burned sites compared to control sites suggests that long-term habitat conditions may worsen on burned sites over time unless additional management actions (additional burns, herbicide, mechanical treatments) are implemented to kill woody midstory plants. These results suggest that the two burn treatments in this study were insufficient to improve habitat conditions for gopher tortoises. However, this does not necessarily mean that burning served no purpose. During the same time period, herbaceous vegetation declined for the control (unburned) treatments in adjacent forest, indicating that burn treatments may have at least prevented further deterioration of habitat conditions.

Analyses of the tortoise radio-tracking data reflect the results found in the vegetative analyses; there were no significant changes found in burrow usage between treatments. Specifically, in the comparison of first and second years' data, there were no differences in how often tortoises moved, which burrow type

was used more often (forested vs. firing point), how many burrows were utilized, or home range. However, it is hard to predict how quickly a population of tortoises would react to changes taking place in a surrounding habitat, even if they were to occur. Gopher tortoises are a long-lived species, and some individuals have probably been utilizing the same burrows for decades. Therefore, if a tortoise is almost exclusively using burrows on ruderal areas, for example, the habitat on those areas would have to degrade at the same time the surrounding habitat is improving in order for that individual to be inclined to make an immediate, permanent home range shift. If the ruderal habitat did not degrade, the tortoise would probably not choose to quickly shift away from burrows that it knows well and has used repeatedly, regardless of the change in condition of surrounding forested habitat. It seems likely that any real changes in the movement patterns and ethology of a population of tortoises will become evident only in a long-term study.

Although reintroduction of fire did not rapidly restore habitat within a three-year period for this study, it is possible that repeated fires may eventually work to restore degraded forested habitat. It is also likely that if the fires had been more intense, results would have been better; but because of weather, safety, and liability constraints it may not be possible to plan a more intense fire. Additional management techniques such as herbicide use, thinning, or mechanical treatments may be necessary for restoration. If these treatments were continued around firing points as part of a long-term management plan, they might cause gradual changes in the type of burrows the tortoises use. One indication of that from this study is the number and type of new burrows that were discovered. Of the 42 burrows discovered after the initial survey in 2002, the largest percentage of them (43%) were in forested areas at burned sites. This could be a result of the initial decrease in woody vegetation at these sites after the prescribed burns (see Fig. 8), but also suggests that there is the potential for tortoises to start using surrounding habitat that either has never been used or has become overgrown.



## 4 CONCLUSIONS/MANAGEMENT RECOMMENDATIONS

Historically, gopher tortoises primarily inhabited pine-dominated forested areas, with sparse woody midstories and dense herbaceous ground cover, that burned every three to five years, often in the growing season. Fire suppression in many of these areas has resulted in development of dense woody midstories and loss of herbaceous ground cover. In our study, reintroduction of a dormant season fire followed by a growing season fire in pine-forested areas with well-developed shrub/hardwood midstories did not result in increase in herbaceous ground cover one year post-burning. Although shrub cover was initially reduced, the increase in stem densities in burned areas indicates that this reduction will be temporary. This suggests that reintroducing fire and returning to a three- to five-year burn regime will not, by itself, result in the desired changes in habitat. The desired habitat conditions (open canopy, sparse woody midstory, and abundant herbaceous vegetation) will have to be restored, either by several consecutive annual burns or by other management techniques. Only after this will a return to a three- to five-year burn regime be adequate to maintain desired conditions.

Based on these results we would make the following recommendations:

- a) Prioritize management of areas that are not high-use military training areas and that provide appropriate habitat conditions for tortoises so that they continue to provide resources to tortoises (continue to burn during growing seasons at sufficiently regular intervals, manage exotic species, etc.). If tortoises inhabit areas that provide adequate conditions for foraging, nesting, thermoregulation, etc., they are less likely to move into training areas.
- b) If prescribed fire is to be used to restore shrub-encroached areas, then burn interval should be increased to annual burns, or as soon as fuel levels permit a fire to carry. Managers must expect to make a long-term commitment to restoring habitat this way. Hotter fires, which would result in more complete kill of woody vegetation, even though they carry the possibility of overstory crown scorch, may also be needed to shift habitat to more desirable conditions.
- c) Combining mechanical (thinning) and/or chemical (herbicides) methods with prescribed fire may be necessary initially to more rapidly reduce midstory and promote return of herbaceous vegetation in shrub-encroached areas.

It should be remembered that even when adjacent forested habitat is improved (in terms of gopher tortoise habitat), it may take years for tortoises

to move out of training areas into these habitats. Since training areas are maintained annually by mowing, these habitats provide open conditions and herbaceous forage necessary for tortoises. Therefore, tortoises that spend most of their time on training areas have little incentive to leave unless increased military activity causes enough increased stress that they seek other areas to inhabit. This is the subject of an ongoing study.

In our study, the amount of time tortoises spent in forested habitats (at all sites) was approximately 18%. This number did not increase during the study, probably because any habitat improvements due to burning were only temporary. However, this does not mean that burning adjacent habitat will not affect tortoise populations over time. The largest percentage of new burrows found since the beginning of the study was in forested areas at burned sites, suggesting that there is potential for tortoises to start using surrounding habitat that either has not been used or has become overgrown. There appears to be no way to cause the tortoises to abandon the firing points, since the sunny openings will always be attractive to them. However, if usage of the improved forest habitat is increased, then risk to the animals from military vehicle use will be reduced. Only after many consecutive years of burning (and/or other management techniques) resulting in a return to desired habitat conditions will we start to see tortoises permanently shift their home ranges to include more of the forested areas.

## LITERATURE CITED

- Auffenberg, W.** (1978) Gopher tortoise, *Gopherus polyphemus* (Daudin). In *Rare and Endangered Biota of Florida. Volume 3: Amphibians and reptiles* (R.W. McDiarmid, Ed.). Gainesville, Florida: University Presses of Florida, p. 33–35.
- Auffenberg, W., and R. Franz** (1982) The status and distribution of the gopher tortoise (*Gopherus polyphemus*). In *North American Tortoise: Conservation and Ecology* (R.B. Bury, Ed.). U.S. Fish and Wildlife Service, Wildlife Research Report 12, p. 95–126.
- Auffenberg, W., and J.B. Iverson** (1979) Demography of terrestrial turtles. In *Turtles: Perspectives and Research* (M. Harless and H. Morlock, Ed.). New York: John Wiley & Sons, p. 541–569.
- Blankenship, E.L., T.W. Bryan, and S.P. Jacobsen** (1990) A method for tracking tortoises using fluorescent powder. *Herp Review*, **21**: 88–89.
- Boyer, W.D.** (1990) Growing-season burns for control of hardwoods in longleaf pine stands. USDA Forest Service, Southern Research Experiment Station. Research Paper SO-256.
- Cox, J., D. Inkley, and R. Kautz** (1987) Ecology and habitat protection needs of Gopher Tortoise (*Gopherus polyphemus*) populations found on lands slated for large-scale development in Florida. Florida Game and Fresh Water Fish Commission Nongame Wildlife Program Technical Report No. 4, Tallahassee, Florida.
- Diemer, J.E.** (1992) Home range and movements of the tortoise *Gopherus polyphemus* in northern Florida. *Journal of Herpetology*, **26**: 158–165.
- Dietlein, N.E., and R. Franz** (1979) Status and habits of *Gopherus polyphemus*. In *Proceedings, 1979 Symposium of the Desert Tortoise Council, Tucson, Arizona*, (E. St. Amant, Ed.), p. 175–180.
- Douglass, J.F.** (1976) The mating system of the gopher tortoise, *Gopherus polyphemus*, in southern Florida. MA Thesis, University of South Florida, Tampa, Florida, 79 p.
- Epperson, D.M., and C.D. Heise** (2001) Population dynamics of the Gopher Tortoise (*Gopherus polyphemus*) at Camp Shelby Training Site. Final report submitted to DoD Legacy.
- Epperson, D.M., and C.D. Heise** (2003) Nesting and hatchling ecology of Gopher Tortoises (*Gopherus polyphemus*) in southern Mississippi. *Journal of Herpetology*, **37**: 315–324.

- Ernst, C.H., and R.W. Barbour** (1972) *Turtles of the United States and Canada*. Lexington, Kentucky: The University Press of Kentucky, 347 p.
- Eubanks, J.O., W.K. Michener, and C. Guyer** (2003) Patterns of movement and burrow use in a population of Gopher Tortoises (*Gopherus polyphemus*). *Herpetologica*, Vol. 59, No. 3, p. 311–321.
- Glitzenstein, J.S., D.R. Streng, and W.J. Platt** (1995) Evaluating effects of season of burn on vegetation in longleaf pine savannas. Florida Game and Fresh Water Fish Commission Nongame Wildlife Program Project Rep., Tallahassee, Florida.
- Landers, J.L., J.A. Garner, W.A. McRae, and J.L. Buckner** (1981) The Gopher Tortoise: Distribution, ecology, and effects of forest management. Endangered Species Investigations E-1 Southlands Experimental Forest. Bainbridge, Georgia: International Paper Company.
- Landers, J.L., W.A. McRae, and J.A. Garner** (1982) Growth and maturity of the gopher tortoise in southwestern Georgia. *Bulletin of the Florida State Museum, Biological Sciences*, **27**: 81–110.
- Leonard, S.W., J.H. Moore, C.M. Duran, D. Rankin, J. Dillon, and D. Wyrick** (1999) Mississippi Military Department Biological Inventory Camp Shelby 1994–1999. Mississippi Natural Heritage Program, Department of Wildlife, Fisheries and Parks and Mississippi Field Office, The Nature Conservancy, Camp Shelby, Mississippi.
- Lohofener, R.** (1982). Gopher tortoise ecology and land-use practices in southern De Soto National Forest, Harrison County, Mississippi. *The Gopher Tortoise and Its Sandhill Habitat. Proceedings of the 3rd Annual Meeting of the Gopher Tortoise Council* (R. Franz and R.J. Bryant, Ed.). Florida State Museum, Gainesville: 50–74.
- McLaughlin, G.S.** (1990) Ecology of gopher tortoises (*Gopherus polyphemus*) on Sanibel Island, Florida. MS Thesis, Iowa State University, Ames, Iowa, 115 p.
- McRae, W.A., J.L. Landers, and J.A. Garner** (1981) Movement patterns and home range of the gopher tortoise. *American Midland Naturalist*, **106**: 165–179.
- Noel, K.** (2005) Artificial and natural nest incubation studies on the determinants of hatching success of gopher tortoise, *Gopherus polyphemus*, eggs in south Mississippi. MS thesis deposited at the University of South Mississippi, Hattiesburg, Mississippi.

- Peet, R.K., T.R. Wentworth, and P.S. White** (1998) A flexible, multipurpose method for recording vegetation composition and structure. *Castanea*, **63**: 262–274.
- Seaman, D.E., and R.A. Powell** (1996) An evaluation of the accuracy of kernel density estimators for home range analysis. *Ecology*, **77**(7): 2075–2085.
- Seaman, D.E., J.J. Millspaugh, B.J. Kernohan, G.C. Brundige, K.J. Raedeke, and R.A. Gitzen** (1999) Effects of sample size on kernel home range estimates. *Journal of Wildlife Management*, **63**(2): 739–747.
- Smith, L.L.** (1995) Nesting ecology, female home range and activity, and population size-class structure of the gopher tortoise, *Gopherus polyphemus*, on the Katherine Ordway Preserve, Putnam County, Florida. *Bulletin of the Florida Museum of Natural History*, **37**(1): 97–126.
- Smith, R.B., D.R. Breininger, and V.L. Larson** (1997) Home range characteristics of radiotagged gopher tortoises on Kennedy Space Center, Florida. *Chelonian Conservation and Biology*, **2**: 358–362.
- Streng, D.R., J.S. Glitzenstein, and W.J. Platt** (1993) Evaluating effects of season of burn in longleaf pine forests: A critical literature review and some results from an ongoing long-term study. In *Proceedings, 18th Tall Timbers Fire Ecology Conference* (S.M. Hermann, Ed.). Tall Timbers Research, Inc., Tallahassee, Florida.
- Weather Underground** (2004) <http://www.wunderground.com>, 21 December 2004.
- Wilson, D.S., H.R. Mushinsky, and R.A. Fisher** (1997) Species profile: Gopher Tortoise (*Gopherus polyphemus*) on military installations in the southeastern United States. U.S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi, Technical Report SERDP-97-10.
- Worton, B.J.** (1989) Kernel methods for estimating the utilization distribution in home range studies. *Ecology*, **70**: 164–168.

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